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SEA-ICE REMOVAL TECHNIQUES FOR WINTER QUARTERS BAY, ANTARCTICA

By

F. W. Brier and K. D. Vaudrey

December 1975

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1. Ice breaking – mechanical trenching I. 61-020

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INTRODUCTION

Docks and harbors in polar regions are difficult to construct and maintain because of ice conditions during much of the year [1]. Prior to Deep Freeze 64 (DF-64),[a] ships supplying McMurdo Station, Antarctica, offloaded all cargo onto the annual sea ice in McMurdo Sound (Figure 1) several miles from the station. The offloading and transportation of cargo from the ships to McMurdo Station were a dangerous and time-consuming operation. In DF-64 an area of fast ice along the north shore of Winter Quarters Bay near McMurdo Station was used effectively as a wharf for ship unloading. Cargo ships were able to offload directly onto trucks and trailers for the short haul to McMurdo cargo yards.

Surface erosion and undercutting of the vertical face by wave action contributed to a gradual deterioration of the natural ice wharf. In 1969, it was estimated that each year 10,000 square feet of surface area was lost to wave action [1]. A more serious problem than the loss of cargo-handling area was the reduced water depth along the face of the wharf.

To prevent further damage to the wharf the Naval Facilities Engineering Command (NAVFAC) designed a protective dock face. In a 4-year period ending in DF-72, 464 feet of steel and timber protective dock facing were installed [2]. In March 1972, a major portion of the newly constructed dock facing was destroyed during a storm [3]. High tides and pounding ice ripped away much of the steel and timber facing, leaving the wharf exposed to more erosion. The water depth at the face of the wharf also became more critical because earth fill was washed into the bay.

As a temporary solution to the problem an artificial ice wharf was constructed on the north side of Winter Quarters Bay during the winter of DF-73. The artificial ice wharf, which was constructed by surface flooding, was 29 feet thick, had a 460-foot landward face, and a width of 170 feet (Figure 2).

In January, 1974, the artificial ice wharf cracked at several locations while the icebreaker USCG Staten Island was attemping to cleave annual sea ice from the seaward face. As a remedial measure bollards were used to tie sections of the artificial ice wharf together during cargo offloading operations. Subsequent discussion indicated that an open-water area adjacent to the seaward face would have prevented the damage.

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[a] The Deep Freeze (DF) year begins July and ends in June.

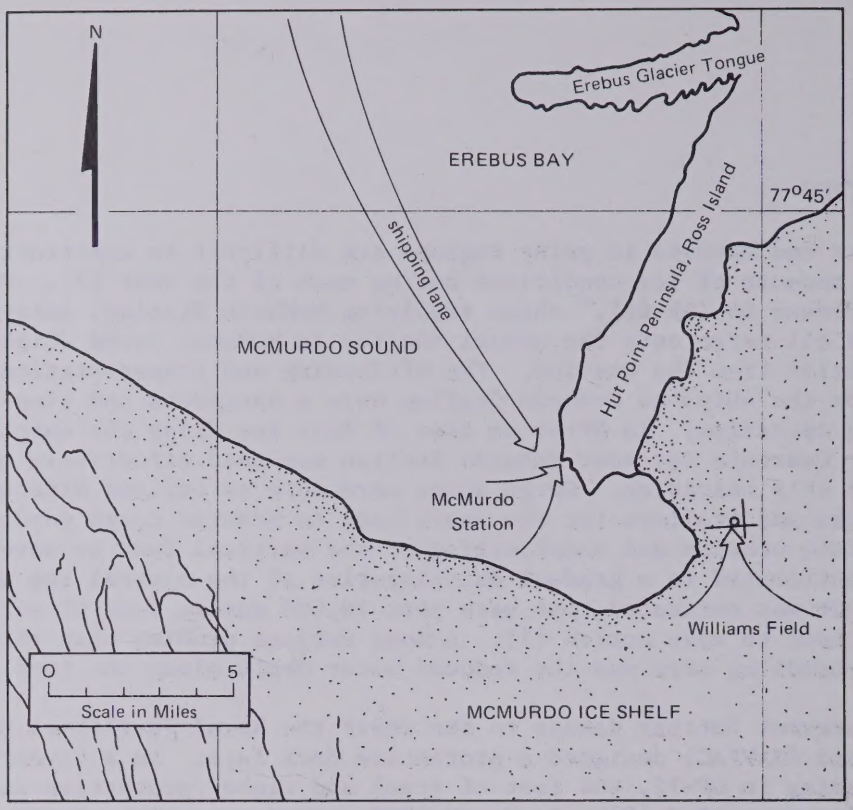


Figure 1. Area map of McMurdo Sound.

Figure 2. Artificial ice wharf during docking of the cargo ship USNS Private John R. Towle, January, 1974.

During June, 1974, the Civil Engineering Laboratory (CEL) conducted laboratory tests on an ice excavation machine for burial of utilities in ice and high-density snow. The machine used in the laboratory tests was a Davis Model TF-700 trencher. The TF-700 is powered by a 30-hp air-cooled engine with mechanical drive to the trencher chain and hydraulic drive to the tracks. The maximum recommended depth for excavating in dirt with normal cutting chain is 72 inches for a 6-inch-wide trench; however, the TF-700 was equipped with a frost chain capable of excavating both ice and frozen earth, but only to a depth of 58 inches for an 8-inch-wide trench. Cutting tests were conducted comparing the commercial tungsten-carbide-tipped teeth with CEL-developed 30-degree conical pointed teeth. The maximum travel speed using the carbide-tipped teeth was 7.5 fpm, compared to 13.9 fpm for the conical teeth when cutting 31 inches of seawater ice.

It was concluded from the laboratory tests that a trenching machine similar to the one tested at CEL could be used to create an open-water area adjacent to the seaward face of the artificial ice wharf. This technical note describes field tests of a trenching machine used for this purpose.

EQUIPMENT DESCRIPTION

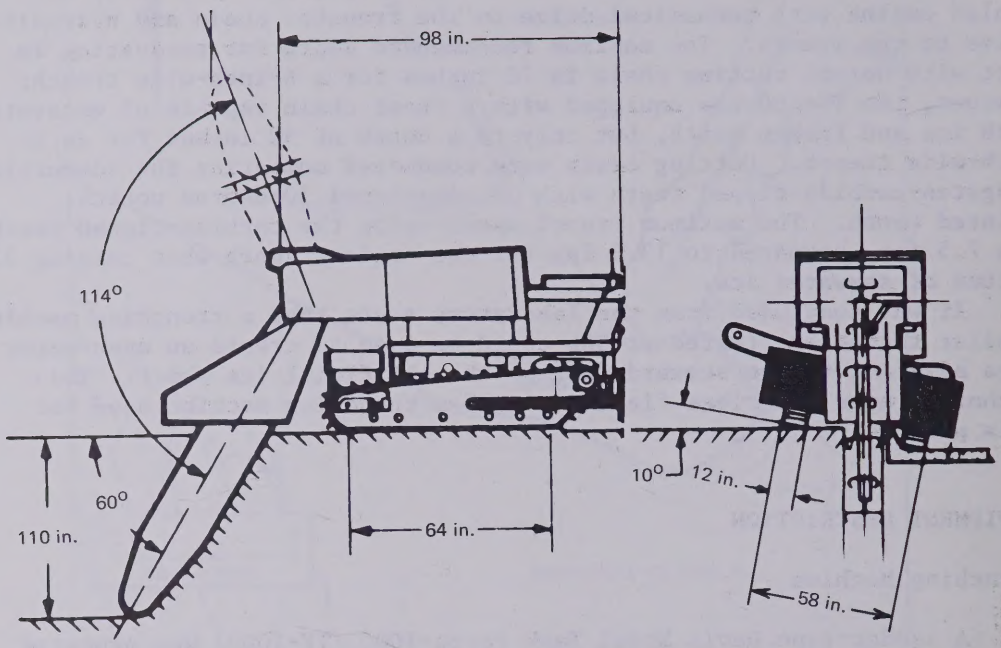
Trenching Machine

A ladder-type Davis Model Task Force-1000 (TF-1000) was procured from Case Power and Equipment for this project. The TF-1000 (Figure 3) is equipped with a 60-hp diesel engine, 86-inch trenching boom, 8-inch frost chain, 10-inch cleat pads, and a roll over protection system. The total cost was $15,612. The TF-1000 weighs about 9,000 pounds and has an overall length of 8 feet 2-3/4 inches without the boom.

The TF-1000 is equipped with a hydra-static drive providing infinitely variable speed control from a two-speed gear transmission. Trenching speeds of 0 to 900 fph are obtainable in low range; transport speeds of 900 to 1,500 fph are obtainable in high range.

Two manually operated hydraulic actuators tilt the entire upper structure of the trencher, including the boom. This allows the machine to cut vertically with tracks resting on slopes up to 20%. The hydraulic power tilt shifts the center of gravity of the machine to maintain stability.

The steering, brakes, clutches, and digging chain are all hydraulically controlled. The digging chain has a hydraulic relief to provide torque limit protection for the driveshaft, cutting teeth, and engine. Dual controls permit operation from either the front or rear of the machine.



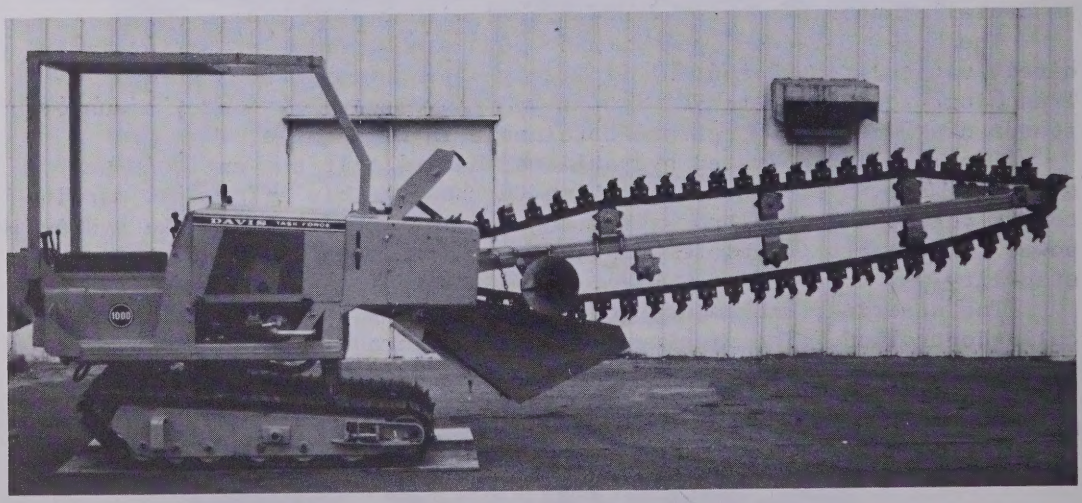


Figure 3. Davis TF-1000 trencher.

Modifications

Two modifications were designed and fabricated for the TF-1000. One was a 2-foot boom extension and the other conical trenching teeth.

Boom Extension. To increase the trenching depth of the TF-1000 to 120 inches a 2-foot boom extension was designed and fabricated. The boom extension consists of a 4-inch-square structural tube with 8-inch-square end plates. The 86-inch boom was cut 42 inches above the end roller, and 1/2-inch plates were welded at the joint to match those on the extension.

Trenching teeth. Various configurations for ice cutting teeth were reviewed for maximum cutting rate and minimum horsepower requirements. It was concluded that teeth with a 30-degree conical point developed by CEL in 1960 for use on an ice dozer were the most suitable configuration. This was confirmed in the laboratory tests of the TF-700. One hundred and fifty conical teeth (Figure 4), which are interchangeable with commercial carbide-tipped teeth, were fabricated for the TF-1000 at a cost of $765.

OPERATIONAL PROCEDURES

It was planned to utilize the TF-1000 to excavate 8-inch-wide trenches completely through the sea ice in Winter Quarters Bay during December 1974. The ice block formed by the cuts then would be towed out of the bay by an icebreaker. The exact trenching pattern could not be selected until a site investigation had been conducted to determine sea-ice thicknesses, ice-wharf face configuration, and surface conditions.

Site Investigation

On 29 and 30 December 1974 a site investigation was conducted in Winter Quarters Bay to determine the trenching pattern. Sea-ice thicknesses ranged between 68 and 74 inches. Melt ponds up to 24 inches deep existed along the seaward face of the artificial ice wharf and adjacent to the shoreline near Scott's Hut (Figure 5). The sea ice in the remainder of the Bay was covered intermittently with melt ponds 4 to 6 inches deep. It was very difficult for people to walk on the sea ice in the Bay. The surfaces of shallow melt ponds, which had refrozen, collapsed under weight. In addition, several refrozen and wet cracks traversed the Bay.

Trenching Pattern

A trenching pattern to minimize melt-pond interference was marked with bamboo poles (Figure 5). Lines AB and GH terminated at a 6-inch-wide wet crack. Lines AB and GH were intentionally laid out to diverge with DF and EG. This was essential if an icebreaker was to tow the blocks of ice out of the Bay.

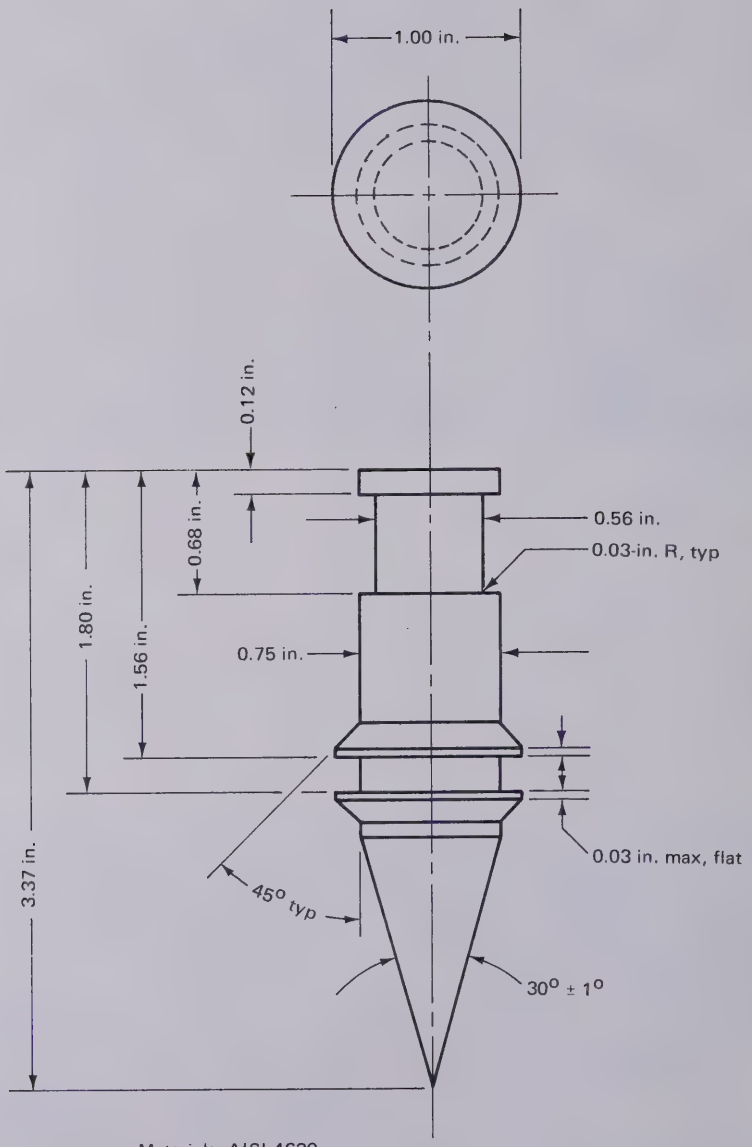


Figure 4. Conical ice chipping teeth.

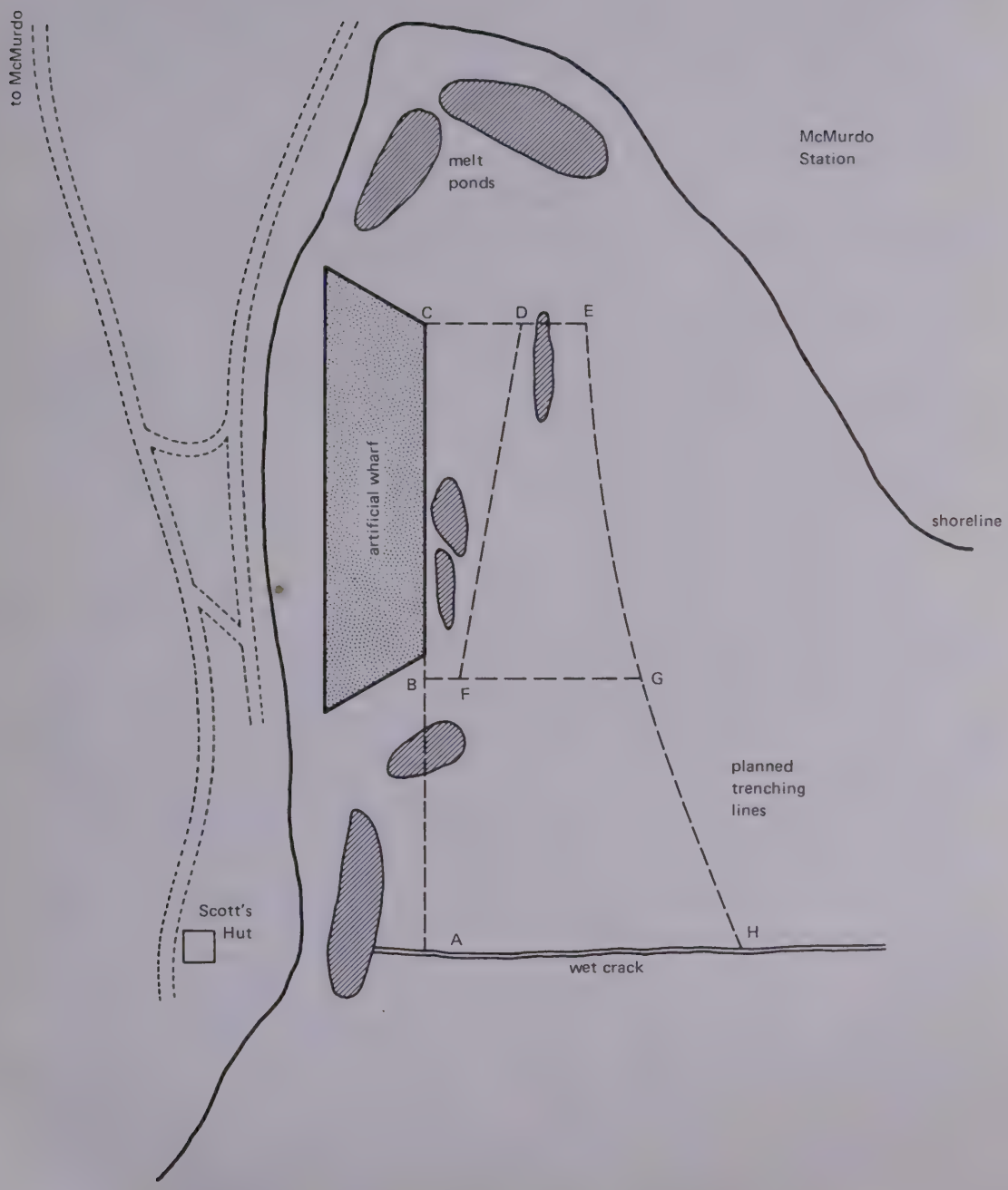


Figure 5. Winter Quarters Bay in December 1974.

Two major obstacles interfered with this trenching pattern. One was a large melt pond, about 2 feet deep and 16 feet wide, which intersected line AB. The second was a 1-1/2-foot-deep by 4-foot-wide melt pond between points D and E; this melt pond was about 30 feet long. Graphic analysis showed that, when equipped with a 2-foot beam extension, the TF-1000 could cut a continuous trench from both sides of a pond 24 feet wide. It was planned to use this procedure at the two locations described above.

Preliminary Trenching Tests

Preliminary trenching tests on the sea ice in Winter Quarters Bay showed that several inches of freeze-back occurred on the top surface of a trench within 6 hours when a cut was made entirely through the ice sheet. Air temperature during the tests was above freezing, but apparently had little affect on the freeze-back rate.

It was observed that a high percentage, more than 80%, of the cuttings was removed from a trench as long as it remained dry; however, once filled with water, approximately 2 feet of ice chips floated in the trench. Ice chips cut by the TF-1000 formed a berm on each side of the trench as it was cut. As the chain moved (cutting the ice), seawater was pumped to the surface; the water then ran back into the trench, carrying ice chips with it. The ice-bath effect of a 2-foot layer of ice chips caused rapid freeze-back.

Several attempts at adjusting the dirt deflector and dirt chute failed to alleviate the ice chip problem.

Another attempt to counter the freeze-back problem utilized partial-depth trenches, 3 to 4 feet deep. Partial-depth trenches were cut in the sea ice, removing most of the ice chips. However, these partial trenches did not remain dry, but soon filled with surface-melt runoff. Although these partial-depth trenches did not refreeze for several days, the final cut was difficult to make because the rough ice surface prohibited tracking with the trencher. Therefore, partially cut trenches were abandoned as a practical method of eliminating the freeze-back problem occurring with fully cut trenches. Other expedient field attempts to circumvent freeze-back, such as dragging heavy anchor chain through the trench, were unsuccessful.

Although the trencher with the standard boom was capable of making 86-inch-deep cuts at a 60-degree angle (Figure 3), it was hoped that a longer boom would aid in removing ice chips from the trench. Therefore, the 2-foot boom extension and 500 pounds of counterweight were added to the trencher. The extended boom made the machine slightly nose-heavy, even with the counter weight. In negotiating several melt ponds, the trencher came close to tipping over on its front end while climbing out of the pond.

Trenching Operation

The trenching operation was initiated on the afternoon of 12 January and completed about 16 hours later, during the early morning hours of 13 January. During this period five trenches (Figure 5) were cut, totaling about 1,800 feet. Trench GH was not cut because of time limitations.

During the trenching operation, lumber was used to support the TF-1000 when cutting through some surface melt ponds. At three locations melt ponds existed in the line of cut that were too deep for the machine to cross. At these locations cuts were made from both sides of the pond to obtain a continuous trench through the ice sheet.

The rough surface of the sea ice made it impossible to maintain a straight cut, even when following a string line (Figure 6). Frequently, the TF-1000 had to be backed up and several feet of trench recut to maintain diverging lines DF and EG.

After trenches AB and BG were completed, the icebreaker USCG Burton Island moved into Winter Quarters Bay and fragmented the sea ice on the seaward side of trench BG (Figure 7). It was observed that trenches AB and BG did in fact serve as crack arresters during icebreaker operations.

After the trenches around the wedge-shaped block (DEGF) were cut, an attempt was made by the icebreaker to tow it away. However, the ship was unable to move it, and it was subsequently fragmented by the icebreaker. At the time towing was attempted, Trench DF had refrozen to a depth of 3 to 6 inches.

Blasting Operation

After the icebreaker had fragmented the sea ice on the seaward side of trench DF, Dr. M. Mellor from the Cold Regions Research and Engineering Laboratory supervised blasting the outboard face of the wharf to obtain a straight, vertical face. Four-inch-diameter holes were drilled through the wharf at 4-foot intervals in a line parallel to and about 10 feet from the edge (Figure 8). A series of controlled explosions fractured the wharf, providing the desired straight vertical face on the line of drill holes. During a test blast for technique development by Dr. Mellor before the icebreakers arrived, the TF-1000 was used to create a stress relief trench, cut in the sea ice parallel to and about 20 feet from the line of test charges.

EQUIPMENT PERFORMANCE

Approximately 24 man-hours were required for assembling the TF-1000 after shipment to McMurdo Station. The boom, chain, counterweights, and roll-over protection system had been removed to facilitate air transport from New Zealand to McMurdo Station. The only difficulty encountered during the assembly was in attaching the frost chain to the boom. The chain was heavy and awkward to handle.

Figure 6. Trencher attempting to follow string line.

Figure 7. TF-1000 trenching in Winter Quarters Bay as icebreaker fragments sea ice.

Figure 8. Blast line on seaward side of artifical ice wharf.

During the preliminary tests on smooth ice, which was essentially isothermal ($26^{o}F$) at the surface, the TF-1000 cut an 8-1/2-inch-wide trench through 72 inches of sea ice at a travel speed of 10 fpm. However, because surface ablation had made the sea ice in Winter Quarters Bay very rough, travel speed had to be reduced to 3 fpm. During the cutting operation the maximum lineal chain speed was measured to be 300 fpm.

The specific energy consumption for the TF-1000 to cut and remove the ice was calculated to be 206 psi. Specific energy is found by dividing the power required to excavate material by the volume rate of material removed. Tests by the U.S. Army Cold Regions Research and Engineering Laboratory [4] showed that many excavating machines deliver about 60% of their rated power to the cutting elements. The calculation was based on this assumption.

The conical teeth were inspected several times during preliminary tests and trenching operations. The wear was imperceptible.

Initially, there was concern that the boom would bind against the side of the trench if the tilt operation was not performed during sloping cuts or if abrupt changes of cutting direction were attempted. These fears were unsubstantiated, because the TF-1000 had sufficient power to cut a wider trench as the boom swung against the side. Although the

recommended boom angle for operation in dirt is 30 degrees from vertical, the trencher operated effectively in ice with the boom in a near-vertical position.

The uneven ice surface caused by severe ablation made it impossible to maintain a straight cut, even while following a string line. As the trencher moved over the undulating surface, constant attention of the operator was required to perform the "tilt" motion to maintain a vertical trench. At the same time, an almost constant braking of the lower track was required to keep the trench straight. Braking of the lower track caused the upper track to slip. Also, as the trencher started down an incline the operator had to lower the boom to assure a full-depth cut. All of these factors caused the trencher to deviate from a straight line.

The machine performed very well during the 16-hour, continuous-trenching operation. The only problem occurred while attempting to cut a refrozen preliminary test trench, about 2 weeks old. The 24-inch-deep ice chip aggregate conglomerate was much harder than the natural ice sheet, and the TF-1000 was unable to cut it. After several unproductive attempts, this area was abandoned in favor of adjacent natural sea ice. The problem remains unexplained, except perhaps the conglomerate of ice chips produces ice with randomly oriented crystal growth, making cleavage by the trencher teeth difficult.

Overall, the trencher was easy to operate and quite simple to learn for the novice operator. From a human-factors standpoint, the machine was extremely noisy and, at times, exhaust fumes drifted back into the operator's face. Both of these problems could be corrected by the addition of an exhaust pipe extension.

FINDINGS

1. The Davis Model TF-1000 Trencher with a 60-hp engine and conical ice cutting teeth is capable of trenching through 72 inches of sea ice at a travel speed of 10 fpm.

2. The TF-1000, as configured during tests at McMurdo Station, Antarctica, did not remove sufficient ice cuttings from the trench to prevent freeze-back. Freeze-back occurred on the surface of the trench within 6 hours.

3. The TF-1000 can be used effectively to cut trenches in sea ice to provide crack arresters for preventing propagation of unwanted cracks.

4. The TF-1000 can be operated on an undulating ice surface, but travel speed is reduced by more than 50%.

CONCLUSIONS

The idea of using a modified earth trencher to eliminate damage to the artificial ice wharf in Winter Quarters Bay, McMurdo Station, Antarctica, has been found to be partially applicable. The performance of the trenching machine was excellent. The 10-fpm cutting speed exceeded initial estimates. However, rapid freeze-back of the trench prevented removal of the sea ice by towing. This necessitated the icebreaker to fragment the sea ice in place.

Had a method for preventing refreezing been available, an ice breaker would have been able to tow the ice blocks, cut with the trenching machine, out of Winter Quarters Bay.

REFERENCES

1. Naval Civil Engineering Laboratory. Technical Note N-1030: McMurdo Ice Wharf-Physical Characteristics and Criteria for Protection, by R. A. Paige. Port Hueneme, CA, Apr 1969.

2. ''Ship Operations, Deep Freeze 73,'' Antarctic Journal of the United States, Vol. VIII, No. 4, Jul-Aug 1973, pp 220-224.

3. Civil Engineering Laboratory. Technical Note N-1376: The Man-Made McMurdo Ice Wharf-History, Construction and Performance, by J. L Barthelemy. Port Hueneme, CA, Feb 1975.

4. Cold Regions Research and Evaluation Laboratory. Technical Note: Cutting Frozen Ground with Disc Saws, by M. Mellor. Hanover, NH, Jul 1972.

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